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METHOD AND APPARATUS FOR
DETERMINING TAX OF A VEHICLE

TECHNICAL FIELD OF THE INVENTION

This invention relates to determining tax of a
vehicle, and more particularly to a system for
5   determining tax of a vehicle using a positioning system.

BACKGROUND OF THE INVENTION

Mobile positioning technology has advanced substantially over the past decade. Many cars, trucks, airplanes, boats, and other vehicles are equipped with devices that provide convenient and reliable mobile positioning using either networks of satellite-based and land-based transceivers or an on-board positioning sensor, such as an inertial navigation system or a dead reckoning system.

Many users of mobile positioning systems, particularly those operating commercial vehicles, also require an accurate determination of tax assessed by one or more taxing regions through which the vehicles travel. Previously, tax determinations were based upon manual reporting and charting of vehicle positions, or recreation of the miles traveled in taxing regions after a trip. For example, one way to determine tax for a vehicle is to estimate the number of miles traveled by the vehicle based upon a corresponding distance taken along a preferred route on a map. This approach, however, may not be suitable for particular applications that require more accuracy in the determination of tax. Consequently, a need has arisen for an apparatus and method that accurately determines tax of a vehicle. Furthermore, operators of commercial vehicles may also require a way of reporting this tax to a remote location. For example, a cellular telephone in a vehicle offers a convenient communications link to report a determined tax.

SUMMARY OF THE INVENTION

In accordance with the present invention, the disadvantages and problems associated with previous techniques used to determine tax for a vehicle have been substantially reduced or eliminated. One aspect of the present invention provides a system for determining a tax of a vehicle using positioning technology.

According to an embodiment of the present invention, an apparatus on a vehicle for determining a tax for the vehicle includes a positioning device. The positioning device determines a plurality of vehicle positions along a route traveled by the vehicle. A memory stores geographic information defining a plurality of regions. A processor is coupled to the positioning device and the memory. The processor receives vehicle positions from the positioning device and geographic information from the memory. The processor determines the distance traveled by the vehicle in the regions in response to the vehicle positions and the geographic information.

According to another embodiment of the present invention, a method for determining a tax for a vehicle traveling through a plurality of taxing regions includes determining a plurality of vehicle positions. Each vehicle position is associated with a taxing region. The tax in each taxing region is determined in response to the vehicle positions associated with that taxing region.

Important technical features of the present invention include improving the accuracy of determining the distance traveled or tax for a vehicle passing through regions using a positioning system. The present invention provides determination of the tax on the vehicle or transmission of vehicle position information for determination at a remote location. Other important technical advantages include reporting tax information to a central location using a wireless communications network, such as the cellular telephone network. Another

important technical advantage of the present invention
includes consolidating tax determinations with the
generation of billing information. Further technical
advantages include determining tax of a vehicle based
5   upon actual miles traveled by the vehicle. Yet another
important technical feature of the present invention
includes taking into consideration any deviation from a
predetermined route when determining distance and tax.
Another important technical advantage of the invention
10   includes reducing the human error associated with
determining distance traveled or tax. Other technical
advantages are readily apparent to one skilled in the art
from the following figures, description, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and for further features and advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, wherein like reference numerals represent like parts, in which:

FIGURE 1 illustrates a system for determining and reporting a tax of a vehicle;

FIGURE 2 illustrates a grid overlaying a map generated in a first embodiment of the invention;

FIGURE 3 illustrates an enlarged portion of the grid shown in FIGURE 2;

FIGURE 4 illustrates a grid overlaying a map generated in a second embodiment of the invention;

FIGURE 5 illustrates an enlarged portion of the grid shown in FIGURE 4;

FIGURE 6 illustrates a table generated in the second embodiment of the invention;

FIGURE 7 illustrates a map showing the operation of a third embodiment of the invention;

FIGURE 8 illustrates an enlarged portion of the map shown in FIGURE 7;

FIGURE 9 is a schematic representation of a mobile unit;

FIGURE 10 is a schematic representation of a dispatch;

FIGURE 11 is a flow chart of the first method for determining tax of a vehicle, using the grid shown in FIGURES 2 and 3;

FIGURE 12 is an alternative flow chart of the first method for determining tax of a vehicle, using the grid shown in FIGURES 2 and 3;

FIGURE 13 is a flow chart of the second method for determining tax of a vehicle, using the grid shown in FIGURES 4 and 5; and

FIGURE 14 is a flow chart of the third method for determining tax of a vehicle, as shown in operation using the map of FIGURES 7 and 8.

DETAILED DESCRIPTION OF THE INVENTION

FIGURE 1 illustrates a system 10 for determining the tax of a vehicle 20 traveling from a point of origin X (located in a taxing region 1) to a destination Y (located in a taxing region 2) across a regional boundary 1-2. System 10 includes vehicle 20 equipped with a mobile unit 22, a dispatch 30, and a communications link 40. System 10 provides an accurate determination of tax for vehicle 20 traveling along route X-Y for each of taxing regions 1 and 2. System 10 may also be used to determine the distance vehicle 20 travels in different regions, without calculating any associated tax. Therefore, all discussions below that relate to determining a tax for vehicle 20 apply equally to determining the distance vehicle 20 travels in any geographic regions for reasons other than tax computation.

FIGURE 1 shows mobile unit 22 on vehicle 20. The present invention contemplates mobile unit 22 being carried by all types of vehicles, including cars, trucks, airplanes, barges, boats, railcars, truck-trailers, or any other moveable object for which it is desirable to determine a tax based upon distance traveled within a taxing region. The taxing regions may be countries, regions, districts, states, counties, cities, particular roads or any other region that may charge a tax based on fuel consumption, road usage, or other activity relating to distance traveled or roads traveled along in the region. Each taxing region may have its own tax structure. Thus, the tax rate in region 1 may differ from the tax rate in region 2. Furthermore, each region may contain toll and non-toll road designations, which may also impact the determination of tax.

Mobile unit 22 comprises an odometer 109 (FIGURE 9) operable to measure the distance traveled by vehicle 20. Odometer 109 can be the odometer originally included in

vehicle 20. Alternatively, odometer 109 can be an
odometer that is more integral to mobile unit 22 than
vehicle 20. In one embodiment of the present invention,
as will be discussed below in more detail, odometer 109

5   provides distance information that is used by mobile unit
22 to determine tax for vehicle 20. Odometer 109 is an
important technical aspect of the present invention
because many taxing authorities currently accept odometer
readings as an accurate measurement of distance traveled

10   by a vehicle. Alternatively, mobile unit 22 may use an
approved mileage database, such as those provided by
Rand-McNally and others, to determine distance traveled.

Using a positioning system 50, mobile unit 22
determines the position of vehicle 20. Specifically,

15   mobile unit 22 comprises a mobile positioning receiver 80
(FIGURE 9) operable to receive positioning information
from positioning system 50. Mobile unit 22 receives
positioning information over positioning information
streams 54 from a plurality of satellites 52. Mobile

20   unit 22 then determines its position fix using
information from positioning information streams 54. The
positioning information comprises accurate satellite
positioning information transmitted by satellites 52 and
pseudorange data represented by the time of arrival of

25   positioning information streams 54 at mobile unit 22.

Positioning system 50 is illustrated as a
satellite-based radio navigation system, such as the
NAVSTAR global positioning system (GPS). The description
uses the NAVSTAR GPS as a representative positioning

30   system 50, but any land-based or satellite-based system
may be used. For example, positioning system 50 may be a
land-based LORAN-C, a space-based GLONASS, or any other
appropriate positioning technology. As shown in
FIGURE 1, positioning system 50 comprises a plurality of

35   satellites 52. In general, positioning system 50

comprises a plurality of space-based or land-based transmitters that emit positioning information.

Satellites 52 maintain accurate and synchronized time and simultaneously transmit positioning information that contains satellite specific and system information required by mobile unit 22 to determine the position fix of vehicle 20. The positioning information transmitted by satellites 52 may include high precision clock and ephemeris data for a particular satellite, low precision clock and ephemeris data for every satellite in a constellation ("almanac data"), health and configuration status for all satellites, user text messages, and other parameters describing operation of positioning system 50.

Positioning system 50 may also comprise additional satellites and one or more positioning receivers. The additional satellites may also communicate positioning information to mobile unit 22. In one embodiment, a positioning receiver 46 may be mounted on a receiver site 44, that is part of communications link 40, to implement differential GPS techniques. Positioning receiver 46 generates correction data that enables mobile unit 22 to more accurately determine the position fix of vehicle 20. Positioning receiver 46 transmits the correction data to mobile unit 22 over any suitable link, such as a vehicle information stream 48.

Alternatively, mobile unit 22 can generate positioning information itself using an on-board positioning sensor. For example, an inertial navigation system on vehicle 20 integrates accelerations imparted to vehicle 20 to determine current position. As another example, a dead reckoning system computes vehicle location based on compass orientation and distance traveled at that orientation. A dead reckoning system on vehicle 20 includes a direction finder, such as a compass, integrated with a distance sensor, such as odometer 109 or a tire rotation counter, to track the

location of vehicle 20 and determine its current position.

In response to the positioning information from positioning system 50 or an on-board positioning sensor, mobile unit 22 determines the position fixes of vehicle 20. These position fixes may comprise standard geographical coordinates such as latitude and longitude.

The interval of time between determinations of a position fix may be configurable by either mobile unit 22 or dispatch 30. The determinations of a position fix may also be continuous. As discussed below, this interval of time dictates the accuracy of the determinations of distance traveled and tax of vehicle 20 in a taxing region.

The present invention contemplates that additional processing of information and determining of the distance traveled and tax in a taxing region may be performed on vehicle 20 by mobile unit 22 or at a remote location, such as dispatch 30 or a host 35. In one embodiment of the present invention, mobile unit 22 determines the distance traveled and tax of vehicle 20 based upon the position fixes, the distance measured by odometer 109, or other information that may be contained within mobile unit 22. After mobile unit 22 has made these determinations, this information can be transmitted to dispatch 30 or host 35 using communications link 40.

In another embodiment of the invention, dispatch 30 or host 35 performs the determination of distance traveled and tax after mobile unit 22 has transmitted vehicle information, including the position fixes and/or the distance measured by odometer 109, to the remote location. Mobile unit 22 thus includes a transceiver 94 (FIGURE 9) through which mobile unit 22 transmits vehicle information to a remote location. In general, mobile unit 22 initiates transmission of information to dispatch 30 or host 35 based on some configurable

condition, such as a predetermined reporting interval, a full memory buffer, a store and forward routine, or a minimum signal strength received from communications link 40.

5   Communications link 40 is coupled to mobile unit 22 on vehicle 20 and allows communication between mobile unit 22 and a remote location, such as dispatch 30 or host 35. In the embodiment shown in FIGURE 1, communications link 40 comprises a cellular telephone

10   network. More specifically, communications link 40 comprises at least one receiver site 44 operable to receive vehicle information from mobile unit 22 and a mobile telecommunications switching office (MTSO) 42 coupling receiver site 44 to dispatch 30. Mobile unit 22

15   determines position fixes and distances, and sends these fixes and distances along with other information to receiver site 44 over vehicle information stream 48. MTSO 42, coupled to receiver site 44, routes the vehicle information to dispatch 30 or host 35. Vehicle

20   information may be encoded using traditional data encoders, such as a modem or a dual-tone multifrequency (DTMF) coder/decoder 110 (FIGURE 9).

       In other embodiments, communications link 40 may be one or a combination of dedicated telephone lines,

25   switched telephone lines, microwave communications links, satellite-based communications links, specialized mobile radio (SMR), enhanced specialized mobile radio (ESMR), a personal communications service (PCS), a citizen's band (CB), a dedicated radio system, such as those used by

30   police and fire fighters, or any other suitable communications link that allows mobile unit 22 to transmit data to or receive data from dispatch 30 or host 35. Communications link 40 may also be an SS7 backbone link or similar network for linking land-line or

35   cellular switches in a public switched telephone network (PSTN). Such a link allows components of the PSTN to

share information for validation, roaming, billing, call routing, and other functions. Communications link 40 may also include intelligence to route information generated at mobile unit 22, dispatch 30, or host 35 to multiple

5   selected sites.

Furthermore, vehicle information stream 48 may be the control channel, paging channel, part of a seized voice or data channel, or overhead message stream currently implemented in cellular telephone technology.

10   Presently, the control channel provides paging of incoming calls, hand-off instructions, and other features of the cellular telephone network, but may be modified by one skilled in the art to include transmission of vehicle information. Vehicle information stream 48 may also be

15   implemented using any other analog or digital communications link between mobile unit 22 and receiver site 44, whether or not the communications link requires seizing of a voice or data channel, and whether or not a data encoder is used.

20   As mobile unit 22 moves from one location to another, vehicle information will be transmitted to different receiver sites 44. Receiver sites 44 are operable to emit signals to mobile unit 22. Mobile unit 22 may then alternatively tune between several signals

25   emitted by receiver sites 44 to determine the strongest signal, usually relating to the nearest receiver site 44. Mobile unit 22 establishes communication with that receiver site 44.

Additionally, there are several developing

30   technologies that may provide a convenient implementation of vehicle information stream 48. For example, cellular digital packet data (CDPD) technology allows integration of data and voice using the existing cellular telephone infrastructure. In a CDPD system, digital packets of

35   data and analog voice segments share the same channel. Other developments in digital cellular communications,

such as code division multiple access (CDMA) and time division multiple access (TDMA), allow digital data and digital voice signals to be interspersed on a communications channel. These technologies integrate

5 digital data transmission in a communications link 40, and therefore provide a convenient implementation scheme for vehicle information stream 48.

Mobile unit 22 may send vehicle information to receiver site 44 in one large packet or in several

10 smaller packets interspersed with other data used for mobile communications. For example, the vehicle information may be packaged in existing, but unused, bytes of the overhead message stream or in a dedicated protocol. One possible implementation would place

15 vehicle information in the extended protocol described in the EIA/TIA-533 mobile communications standard, which provides for bidirectional communication between mobile unit 22 and receiver site 44.

Because dispatch 30 and host 35 are coupled to

20 communications link 40, dispatch 30 and host 35 can communicate with mobile unit 22. Host 35 performs the management and control functions for one or more fleets of trucks. Therefore, system 10 may include many hosts 35 associated with trucking companies, delivery

25 services, or other organizations with vehicles 20 equipped with mobile units 22. Host 35 may receive vehicle information directly from communications link 40. If distance and tax for vehicles 20 have not been determined, host 35 may make these determinations.

30 Alternatively, dispatch 30 may receive and process vehicle information from communications link 40 and then route such information to host 35. Furthermore, host 35 can transmit information to mobile unit 22 either directly using communications link 40 or indirectly

35 through dispatch 30. For example, host 35 may generate destination information for vehicle 20 and transmit this

information over a communications link to dispatch 30.
Such destination information may include one or more
destinations, appointment information such as a
corresponding appointment time for each destination

5   specified, routing information, information regarding
tasks to be performed at each destination specified,
average travel time to each destination, rush hour and
traffic information, and weather information. Dispatch
30 collects destination information from several hosts 35

10   and transmits this information to vehicles 20.
Alternatively, host 35 may transmit destination
information to vehicles 20 over communications link 40.
In essence, some of the functions performed by dispatch
30 may be distributed among several hosts 35. For

15   clarity, the remainder of this description will focus
primarily on the functionality of dispatch 30, but it is
understood that host 35 can perform some or all of the
functions performed by dispatch 30.
        Dispatch 30 receives the vehicle information

20   generated by mobile unit 22 for vehicle 20 using
communications link 40. In particular, dispatch 30
contains a modem or DTMF coder/decoder 120 (FIGURE 10)
that receives vehicle information from MTSO 42. Dispatch
30 may comprise an input-output device 126 (FIGURE 10)

25   operable to present visually or audibly the vehicle
information at dispatch 30 once the information has been
received by dispatch 30. For example, input-output
device 126 displays vehicle information on a map showing
that vehicle 20 is traveling along route X-Y between

30   point of origin X and destination Y.
        Dispatch 30 may perform additional processing of the
information received from mobile unit 22 over
communications link 40. As discussed above, the present
invention contemplates that in some embodiments mobile

35   unit 22 does not perform all the determinations necessary
for distance traveled and tax of vehicle 20 in a taxing

region. Thus, in some cases, in response to vehicle information, dispatch 30 determines the distance traveled by and associated tax for vehicle 20 in each taxing region through which vehicle 20 travels. As will be explained below in more detail, dispatch 30 may determine distance traveled and tax for vehicle 20 using one of several methods.

Dispatch 30 transfers vehicle distance, tax information, and actual payment for taxes to taxing authority 32. Taxing authority 32 can generate a tax bill for vehicle 20 or actually receive money and generate a receipt for taxes paid. Transfer of money directly to taxing authority 32 can be accomplished by physically printing and mailing a check, or through any suitable electronic funds transfer technology, such as the electronic data interchange (EDI). Automatic payment of taxes to taxing authority 32 streamlines the tax collection process, reduces potential errors and tardiness in tax computation and payment, and decreases the number of personnel required to compute and collect taxes. When vehicle 20 has already paid a portion of the taxes at the time of fueling or at other times, then the total taxes due taxing authority 32 can be reduced by the amount of the prepaid taxes. Prepaid tax information can be generated at vehicle 20 either automatically or by operator intervention.

Dispatch 30 also generates information that may be sent to vehicle 20 using communications link 40. For example, one function of dispatch 30 may be to generate destination information, as described above, for vehicle 20. Dispatch 30 can also configure the interval of time between position fix determinations by mobile unit 22. Generally, dispatch 30 may transmit to mobile unit 22 any information that facilitates the control or monitoring of vehicle 20.

In the alternative, vehicle information may be loaded into dispatch 30 using any suitable device, such as a keypad, a direct connection, or any suitable removable storage media. Furthermore, vehicle

5   information may be communicated to dispatch 30 using a local wireless link. In some cases, distance traveled and tax in a taxing region do not need to be determined immediately after vehicle 20 has reached its destination. Billing charges may be collected later. In order to

10 avoid unnecessary telecommunications charges associated with using telecommunications link 40, vehicle information may be stored on vehicle 20 and later downloaded to dispatch 30 when vehicle 20 has returned to dispatch 30.

15   System 10 supports reporting of vehicle distances logged in predefined regions. When the predefined regions correspond to boundaries of taxing authorities, system 10 also provides a more accurate determination of vehicle taxes than currently available systems. It may

20 provide these determinations near instantaneously or "on the fly." These determinations may consider the specifics of each trip, such as the route traveled by vehicle 20, actual mileage traveled within a taxing region, actual time and mileage at which vehicle 20

25 traveled from one taxing region into another, and points through which vehicle 20 passes along a particular route. In some applications, low frequency and low accuracy determinations are sufficient. Other applications, however, require greater accuracy and higher frequency

30 determination in near real time. For example, vehicle 20 may carry packages for delivery to different stops along route X-Y. In some cases, it is desirable to bill the party receiving a package for delivery charges at the moment when the package is delivered. The present

35 invention provides determination of the tax attributable to that delivery when the package is received. Because

these determinations may be performed at fixed time intervals, on-demand, or as a result of a predetermined reporting event, billing may accurately be apportioned between deliveries. Furthermore, the present invention

5   allows for adjustments in billing to reflect changes in tax that may be caused by additional distances traveled, such as in the case of road closures.

System 10 supports the remote sending of vehicle information to dispatch 30 from vehicle 20. In most

10   cases, billing statements are generated at a central location, such as dispatch 30. The billing statements may include delivery charges. Delivery charges, in turn, take into account tax charges. Thus, system 10 provides that tax determinations may be consolidated with the

15   generation of billing information. In this way, total taxes for vehicle 20 can be apportioned to particular deliveries, which results in more accurate billing.

System 10 permits determination of tax for vehicle 20 based upon actual mileage driven by vehicle 20 in

20   taxing regions. For example, referring to FIGURE 1, at the moment vehicle 20 leaves origin X to travel to destination Y, the tax for vehicle 20 would be based upon the distance traveled in region 1 along route X-Y and the distance traveled in region 2 along route X-Y. Suppose,

25   however, that a severe storm forces vehicle 20 to detour from route X-Y at point D. Vehicle 20 must then travel through point Z in order to reach destination Y. Because the present invention determines tax based upon actual vehicle positions and distances traveled, as will be

30   discussed in more detail below, system 20 would be able to provide an accurate tax determination even if vehicle 20 is forced to deviate from route X-Y.

System 10 can also adjust the tax computation based on the specific route traveled by vehicle 20. For

35   example, a taxing region may contain both toll and non-toll roads. If the toll road is privately maintained

and vehicle 20 pays the toll at the time of use, then the total distance traveled in the taxing region for purposes of tax calculation may be reduced by the distance traveled on the toll road. There may also be other

5   adjustments to computed tax based on route, such as flat tolls for using a road or bridge. Using system 10, taxing authority 32 could easily and inexpensively account for and collect flat tolls or usage fees for roads and bridges traveled by vehicle 20. A computed tax

10   may also depend on the route taken, whereas some roads carry a different flat tax or rate from others. System 10 can support this and other computations of tax based on the route of vehicle 20.

Furthermore, vehicle information and tax for vehicle

15   20 are automatically determined. Any human error in inputting the vehicle information or determining the tax is substantially reduced or eliminated. For example, like the present invention, some previous methods to determine tax use an odometer to measure the distance

20   traveled by the vehicle. These methods, however, require that the operator of a vehicle record the mileage displayed on the odometer when the vehicle travels from one taxing region into another. This mileage is then used as the basis for calculating tax for the vehicle.

25   If the operator forgets to record the mileage shown on the odometer, however, the determination of tax would be inaccurate. Because the present invention is able to determine when vehicle 20 has traveled from one taxing region into another and to automatically record the

30   mileage at that moment, the error associated with previous methods is eliminated. Also, since the operator of vehicle 20 is not distracted from the primary duty of driving vehicle 20, the risk of vehicle 20 being involved in an accident is reduced.

35   In system 10, dispatch 30 allows monitoring of at least one vehicle 20 equipped with mobile unit 22. A

large company may operate dispatch 30 to monitor a
plurality of vehicles 20 equipped with mobile units 22.
Smaller companies with more limited resources could pool
together to either jointly operate dispatch 30 or employ
5   an independent firm to operate dispatch 30. It should be
understood that the present invention contemplates any
number and arrangement of dispatches 30 to monitor one or
more fleets of vehicles 20.

        FIGURES 2-8 disclose three embodiments of the
10   present invention. In particular, FIGURES 2 and 3
illustrate a region grid 60 that is integral to a first
method for determining the tax of vehicle 20. FIGURES
4-6 illustrate a vehicle position grid 65 and an
associated table 70 that are integral to a second method
15   for determining the tax of vehicle 20. FIGURES 7 and 8
illustrate a map showing the operation of a third method
for determining the tax of vehicle 20.

        Generally, a method for determining a tax for
vehicle 20 traveling through a plurality of taxing
20   regions includes determining a plurality of vehicle
positions, associating each vehicle position with a
taxing region, and determining the tax in each taxing
region in response to the vehicle positions associated
with the taxing region. The present invention
25   contemplates three specific methods for executing the
general method.

        In the first method, which is associated with
FIGURES 2 and 3, mobile unit 22 computes a plurality of
position fixes using either positioning system 50 or an
30   on-board positioning sensor. These position fixes are,
actual locations over which vehicle 20 has traveled. As
discussed above, position fixes may be in the form of
standard geographical coordinates such as latitude and
longitude. Mobile unit 22 may then generate vehicle
35   positions between the position fixes by interpolation.
Interpolation is more suited for computations at a remote

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location, such as dispatch 30, host 35, or taxing
authority 32, where the granularity of the location data
may be sacrificed to reduce the amount of data
transmitted from mobile unit 22. Mobile unit 22 can also

5   perform position fixes at a more frequent, near
real-time, interval. This provides an accurate
determination of region boundaries without the need for
interpolation. The decision to interpolate and the
number of interpolated points depends on the frequency of

10   position fixes and the size of the cells in region grid
60.

       In a second method, which is associated with FIGURES
4-6, mobile unit 22 computes a plurality of position
fixes using either positioning system 50 or an on-board

15   positioning sensor. Depending on the frequency of the
position fixes and the cell size of grid 65, a number of
vehicle positions may be generated by interpolating
between position fixes. Mobile unit 22 then relates
position fixes to predetermined vehicle positions.

20   Predetermined vehicle positions are defined as
significant geographical points, such as cities, towns,
boundaries between taxing regions, or intersections of
major highways. Predetermined vehicle positions and
distance between predetermined vehicle positions may be

25   determined from any mileage database, such as those ALK
provided by Rand-McNally, (LK) or others. In the
preferred embodiment, the taxing authorities accept tax
calculations based on these mileage databases Vehicle
position grid 65, illustrated in FIGURES 4 and 5,

30   contains individual cells associated with predetermined
vehicle positions. Using the predetermined vehicle
positions of vehicle position grid 65, mobile unit 22
reconstructs the route traveled by vehicle 20. Table 70,
illustrated in FIGURE 6, contains taxing information and

35   distances between the predetermined vehicle positions set
forth in vehicle position grid 65. Using table 70,

mobile unit 22 determines a distance and tax for vehicle 20.

In a third method, which is associated with FIGURES 7 and 8, mobile unit 22 also computes a plurality of position fixes using either positioning system 50 or an on-board positioning sensor. Like the first method, these position fixes constitute actual locations over which vehicle 20 has traveled, and may be in the form of latitude-longitude coordinates. Unlike the two previous methods, this method does not incorporate a grid. Rather, mobile unit 22 utilizes position fixes to determine the current taxing region and odometer 109 to determine distance traveled by vehicle 20 in the taxing region.

The first, second, and third methods will be discussed in more detail below in conjunction with a description of FIGURES 2-8. In the three embodiments of the invention illustrated in FIGURES 2-8, the steps may be performed either wholly on vehicle 20 by mobile unit 22 or partly on vehicle 20 and partly at a remote location, such as dispatch 30, host 35, or taxing authority 32. As will be explained in more detail below, if the steps are performed on vehicle 20, a processor 100 (FIGURE 9) that is part of mobile unit 22 makes the determinations. Similarly, if the steps are performed at dispatch 30, a central controller 122 (FIGURE 10) makes the determinations. To better distinguish the three methods and for clarity, the following explanation of the methods disclosed in FIGURES 2-8 assumes that all steps are performed on vehicle 20. It must be understood, however, that one or more steps in any of the three methods may also be performed at a remote location such as dispatch 30.

FIGURE 2 illustrates region grid 60 overlaying a map generated in one embodiment of the invention. The map shows three taxing regions defined as region 1, region 2,

and region 3. The regions may be representative of countries, regions, states, counties, districts, cities, or any other region for which it is desirable to determine a tax based on distance traveled in the region.

5   Each taxing region may have a different tax structure and/or rate. For example, region 1 may assess tax at a first rate, whereas region 2 may assess tax at a second rate. Several routes throughout the regions are defined in part by points A, B, C, D, E, F, G, and H. These

10   points may represent cities, boundaries between regions, or any other landmark or geographic location that may define a route. For example, points A, B, E, F, G, and H represent cities within a particular region. Points C and D represent points on the border between two regions.

15   Region grid 60 disclosed in FIGURE 2 comprises a plurality of cells. Each cell is associated with the taxing region (either region 1, 2 or 3) within which it is located. All cells are approximately equal in size. Preferably, a cell would be located wholly in one region

20   or another. In some cases, however, such as when the boundaries between regions are not straight lines, a cell may be partially located in a plurality of regions. In this latter case, the cell may be associated with the region in which most of the cell is located. Software

25   may be used to fill in the data associated with each cell of region grid 60. This data may include the region associated with the cell, geographical coordinates defining the cell, or routes traveling over the area represented by the cell.

30   The area represented by the cells is configurable. That is, the cells may represent one square mile parcels, five square mile parcels, ten square mile parcels, or other predefined areas. The cells may be squares, rectangles, circles, polygons, or any other geometric

35   construct that facilitates the definition of a region. The area represented by the cells determines the accuracy

of the tax determination. For instance, suppose that a
cell is partially located in several regions. The cell
is associated with a single taxing region. If the area
represented by the cell is one square mile, the error
5   generated by associating a single region with the cell
would be less than if the area represented by the cell is
ten square miles.

     FIGURE 3 illustrates an enlarged portion of region
grid 60 disclosed in FIGURE 2. FIGURE 3 shows route
10   B-C-D over which vehicle 20 travels. As vehicle 20
travels along route B-C-D, mobile unit 22 obtains
position fixes for vehicle 20 at points o, p, q, r, s,
and t.

     If interpolation is performed, the step of
15   determining a plurality of vehicle positions from a set
of position fixes is executed as follows. Mobile unit 22
on vehicle 20 establishes a plurality of position fixes
o, p, q, r, s, and t using position system 50 or an
on-board positioning sensor. Processor 100, which is
20   part of mobile unit 22, determines a route traveled by
vehicle 20 in response to the position fixes o, p, q, r,
s, and t. In particular, the route of vehicle 20 is
represented by lines o-p, p-q, q-r, r-s, and s-t
connecting position fixes o, p, q, r, s, and t.
25   Processor 100 then divides each line into a plurality of
segments. The end point of each segment, shown as the
dots on lines o-p, p-q, q-r, r-s, and s-t, defines a
vehicle position along the route of vehicle 20. In this
manner, mobile unit 22 can generate several vehicle
30   positions for each position fix provided by positioning
system 50 or an on-board positioning sensor.

     The length of each segment may be proportioned to
the size of the cells in region grid 60. As discussed
above, if frequent position fixes are taken, there may be
35   no need to interpolate between the position fixes to
generate additional vehicle positions. With or without

interpolation, the spacing between position fixes (or
vehicle positions if interpolation is used) should be
coincident with the cell size, so that a transition from
one cell to an adjacent cell will be detected. It should

5   be understood that any reference to vehicle positions
includes interpolated vehicle positions, position fixes,
or both.

Next, the step of associating each vehicle position
with a taxing region is executed as follows. Processor

10   100 references a map overlaid with a plurality of cells,
shown generally by grid 60 in FIGURE 2 and in detail in
FIGURE 3. The map and associated grid may be generated
by processor 100, but is normally produced by another
computer or person and loaded into mobile unit 22 for use

15   by processor 100. Each cell is associated with a taxing
region 1, 2, or 3. One or more vehicle positions may be
contained within a single cell. Processor 100 identifies
the cell containing the vehicle position. Processor 100
then associates the vehicle position with the taxing

20   region associated with the cell.

Next, the step of determining the tax is performed
as follows. Processor 100 determines the distance
traveled in each taxing region in response to the vehicle
positions associated with that taxing region. Processor

25   100 can determine distance by reading odometer 109
(FIGURE 9) at each position fix. Another way in which
processor 100 can determine distance is by summing up the
number of segments within a taxing region and multiplying
that figure by the distance represented by each segment.

30   For example, if vehicle 20 has traveled 24 segments in a
taxing region and each segment represents 10 miles, then
processor 100 calculates that vehicle 20 has traveled 240
(24 X 10) miles in the region.

Another way in which processor 100 can determine

35   distance for vehicle 20 is by calculating the distance of
each segment using standard geometrical formulae and then

summing up these distances. For example, if vehicle 20
has traveled segments of 10 miles, 12 miles, and 9 miles
in a taxing region, then processor 100 calculates that
vehicle 20 has traveled 31 (10 + 12 + 9) miles within
5   that region. A calculation based on straight line
segments may not accurately represent curvature of the
road. Therefore, distance can be adjusted by multiplying
the sum of the straight line segments by a curvature
factor (i.e. 1.1), which represents an estimate of the
10   increase in distance due to road curvature. Different
curvature factors for different roads may be used by
mobile unit 22. Other curve fitting techniques or spline
constructions may also be used to more accurately
determine distance traveled on the roads. Processor 100
15   then determines a tax in the region in response to the
computed distance traveled by vehicle 20 in the region.
Mobile unit 22 may then transmit the determined distance
and tax to a remote location, such as dispatch 30.
            An alternative embodiment of the invention is
20   disclosed in FIGURES 4-6. Whereas the first method
disclosed in FIGURES 2 and 3 focuses upon taxing regions,
the second method disclosed in FIGURES 4-6 focuses upon
predetermined vehicle positions which correspond to
distinct geographic landmarks or monuments, such as
25   cities, intersections between routes, or intersections of
routes with regional boundaries. FIGURE 4 illustrates
vehicle position grid 65 overlaying a map. Similar to
FIGURE 2, the map in FIGURE 4 is divided into taxing
regions 1, 2, and 3. Several routes throughout the
30   regions are defined in part by points A, B, C, D, E, F, G
and H. As discussed above, these points may represent
cities, boundaries between regions, or any other landmark
or geographic location that may define a route. These
points are associated with predetermined vehicle
35   positions. Vehicle position grid 65 comprises a
plurality of cells, which can be approximately equal in

size. Normally, vehicle position grid 65 is based on an approved mileage database, such as those provided by Rand-McNally, ALK, and others.

Unlike region grid 60, the cells in vehicle position grid 65 are associated with the predetermined vehicle positions corresponding to points along the route traveled by vehicle 20. That is, the cells contain A, B, C, D, E, F, G, or H associated with the predetermined vehicle position to which it is most closely located. In some instances, however, one part of the cell may be more closely located to one predetermined vehicle position whereas another part of the cell may be more closely located to another predetermined vehicle position. In such a case, the cell is associated with the predetermined vehicle position to which most of the cell is more closely located. Software may be used to fill in the data contained within each cell. For example, vehicle position grid 65 may be completed by a program using a spiraling or an expanding radius technique originating at each predetermined vehicle position to fill the cells. Some outlying cells are not associated with any predetermined vehicle positions.

The number of predetermined vehicle positions contained in vehicle position grid 65 dictates the accuracy of the distance and tax determinations for this method. That is, if more predetermined vehicle positions are used, accuracy will be increased. For example, suppose vehicle 20 travels from Dallas to Los Angeles. Further suppose that vehicle position grid 65 only has Dallas, Los Angeles, and Phoenix as predetermined vehicle positions. As will be discussed below, for any two predetermined vehicle positions of vehicle position grid 65, there will be corresponding distances and taxes. Vehicle 20, however, may travel to Los Angeles from Dallas via Phoenix along at least two different routes, one of which is longer than the other. One route takes

vehicle 20 through Amarillo, whereas another route takes
vehicle 20 through El Paso. The route through Amarillo
is longer. The determination of distance and tax for
vehicle 20 would be inaccurate if the corresponding

5   distances and taxes are based upon the route through El
Paso, but vehicle 20 actually travels through Amarillo.
If Amarillo and El Paso are also included as
predetermined vehicle positions in vehicle position grid
65, however, there would be separate corresponding taxes

10   and distances for each of the two routes described above.
Thus, the accuracy of the determination would be
increased.

       A complete trip of vehicle 20 from Dallas to Los
Angeles may include small distances at the beginning and

15   end of the trip that can be added to the total distance
traveled. For example, if the trip begins in Fort Worth
(approximately thirty-five miles from Dallas), but the
first predetermined vehicle position is Dallas, then
mobile unit 22 should add the additional thirty-five

20   miles traveled between Fort Worth and Dallas to the
calculation. Similarly, if Los Angeles is the last
predetermined vehicle position on the trip, but vehicle
20 continues a short way to its destination in Pasadena,
then this distance should be added to the calculation.

25   An additional calculation may also be needed when vehicle
20 travels into outlying cells of vehicle position grid
65 that are not associated with any predetermined vehicle
positions. In this situation, mobile unit 22 can adopt a
hybrid technique that uses the other methods described to

30   compute distance and tax determinations when vehicle 20
travels into outlying cells.

       FIGURE 5 illustrates an enlarged portion of vehicle
position grid 65 disclosed in FIGURE 4. FIGURE 5
illustrates route B-C-D traveled by vehicle 20 in taxing

35   regions 1 and 2. In operation, mobile unit 22 takes
position fixes o, p, q, r, s, and t for vehicle 20 using

positioning system 50 or an on-board positioning sensor. The position fixes o, p, q, r, s, and t are then related to predetermined vehicle positions, which establishes the route B-C-D traveled by vehicle 20. The determination

5   for tax in this method can use the actual distance between points B, C, and D or highway mileage derived from a mileage database. As discussed below, the operator of vehicle 20 may record the actual mileage between the predetermined vehicle positions.

10   The general steps for this second method using vehicle position grid 65 of FIGURE 4 are the same as for the first method using region grid 60 of FIGURE 2. That is, a method for determining a tax for vehicle 20 traveling through a plurality of taxing regions includes

15   determining a plurality of vehicle positions, associating each vehicle position with a taxing region, and determining the tax in each taxing region in response to the vehicle positions associated with the taxing region.

       The step of determining a plurality of vehicle

20   positions is performed as follows. Mobile unit 22 establishes a plurality of position fixes using positioning system 50 or an on-board positioning sensor. Depending on the frequency of position fixes and the cell size of grid 65, mobile unit may also generate vehicle

25   positions between position fixes by interpolation. A map is generated with a plurality of cells, shown generally by vehicle position grid 65 in FIGURE 4. Taxing regions are defined on the map. Each cell is associated with a predetermined vehicle position. Processor 100 next

30   associates each position fix with a cell in vehicle position grid 65, which identifies a predetermined vehicle position. Using the predetermined vehicle positions associated with the position fixes, processor 100 reconstructs the route traveled by vehicle 20 through

35   vehicle positions B, C, and D.

In this particular method, the step of determining the tax is executed as follows. Processor 100 utilizes a database containing the predetermined vehicle positions, the corresponding distance in each taxing region between

5   vehicle positions, and the tax associated with each taxing region between predetermined vehicle positions. Processor 100 determines the distance traveled by vehicle 20 in each taxing region by referencing the database for the distance between each predetermined vehicle position

10   along the route traveled by vehicle 20. Processor 100 then determines the tax in each region by referencing the database for the tax associated with each taxing region between the predetermined vehicle positions along the route traveled by vehicle 20. A more detailed

15   explanation of this method is set forth in the description for FIGURE 13.

FIGURE 6 illustrates table 70 generated in the embodiment of the invention disclosed by FIGURES 4 and 5. Table 70 may be referenced in order to determine distance

20   traveled and tax of vehicle 20 between any two predetermined vehicle positions that are associated with the cells of vehicle position grid 65.

Table 70 includes a plurality of sections. The first section, which comprises column 71, contains a

25   first predetermined vehicle position and a second predetermined vehicle position. In particular, the predetermined vehicle positions in column 71 correspond to the predetermined vehicle positions associated with the cells of vehicle position grid 65. These pairs of

30   predetermined vehicle positions define one leg of the route traveled by vehicle 20.

A distance section 72 contains the distance in each taxing region traveled by vehicle 20 between first and second predetermined vehicle positions. Distance section

35   72 may be further separated into region distance columns 74, 75, and 76. Each of these columns contains the

distance traveled by vehicle 20 between the first and
second vehicle positions within a particular taxing
region. Specifically, region distance column 74 contains
miles traveled in region 1, region distance column 75
5   contains miles traveled in region 2, and region distance
column 76 contains miles traveled in region 3. Each leg
of the route, specified in column 71, can include one or
more entries in region columns 74, 75, and 76. For
example, route C-D includes sixty-five miles in taxing
10   region 2 and five miles in taxing region 3.

A tax section 73 contains a tax for taxing regions
between first and second predetermined vehicle positions.
Tax section 73 may be further divided into region tax
columns 77, 78, and 79. Each of these columns contains a
15   tax for vehicle 20 between first and second predetermined
vehicle positions for a particular taxing region. Region
tax column 77 contains the dollar amount of tax for
region 1, region tax column 78 contains the dollar amount
of tax for region 2, and region tax column 79 contains
20   the dollar amount of tax for region 3. These taxes may
be based on a tax rate per miles traveled, a flat tax for
a predefined range of miles traveled, fees for traveling
over particular roads or bridges, or any other tax
computation based on the route of vehicle 20.

25   Processor 100 references table 70 after processor
100 has determined that vehicle 20 has traveled between
two predetermined vehicle positions. For example,
referring to FIGURE 5, after processor 100 has determined
that vehicle 20 has passed through point D along route
30   B-C-D, processor 100 references line 3 in table 70 which
corresponds to route C-D. By referencing distance
section 72, processor 100 determines that vehicle 20
traveled 65 miles within region 2 between points C and D.
By referencing tax section 73, processor 100 determines
35   that vehicle 20 incurred $.30 of tax in region 2 and $.02
of tax in region 3 while traveling along route C-D. This

information may then be displayed on output device 104 (FIGURE 9) of mobile unit 22 or input/output device 126 (FIGURE 10) at dispatch 30.

Another embodiment of the invention is disclosed in FIGURES 7 and 8. Unlike the first method disclosed in FIGURES 2 and 3 and the second method disclosed in FIGURES 4-6, the third method disclosed in FIGURES 7 and 8 does not use a grid pattern. Rather, this method uses odometer 109 in conjunction with a geographical database to determine distance traveled by and tax for vehicle 20. In particular, FIGURE 7 illustrates a map showing the operation of this embodiment of the invention. The map is divided into taxing regions 1, 2, and 3. A plurality of routes through the regions are defined in part by points A, B, C, D, E, F, G, and H. Again, these points may represent any landmark or geographic location that may define a route, such as a city, a boundary between regions, an intersection of a route with a boundary, or an intersection of two or more routes.

The geographical database contains information defining a plurality of taxing regions. This geographic information may include coordinates defining regional boundaries, the intersections of routes with regional boundaries, or any other information that allows a processor to determine that vehicle 20 has traveled from one region into another. For example, the geographical database may include a pair of latitude-longitude coordinates which represent the endpoints of a line corresponding to the boundary between taxing region 1 and taxing region 2. The geographical database can define a set of polygons or other geometrical constructs that define the taxing region. The geographical database may also comprise line segments, splines, or curves that define the boundary between taxing regions. Using any definition of taxing region boundaries or area, processor

100 can determine that vehicle 20 has moved from one region into an adjacent region.

FIGURE 8 illustrates an enlarged portion of the map shown in FIGURE 7. FIGURE 8 illustrates route B-C-D traveled by vehicle 20 in taxing regions 1 and 2. Mobile unit 22 takes position fixes o, p, q, r, s, and t for vehicle 20 using either positioning system 50 or an on-board positioning sensor. The position fixes o, p, q, r, s, and t are then related to a taxing region. Mobile unit 22 records the reading of odometer 109 at each of the position fixes o, p, q, r, s and t, as shown in the mileage readings in FIGURE 8. The determination of tax in this third method is based upon the actual distance measured by odometer 109 between position fixes.

The general steps for this third method using the map of FIGURES 7 and 8 are similar as for the first two methods disclosed in FIGURES 2-6. Specifically, as stated above, a method for determining a tax for vehicle 20 traveling through a plurality of taxing regions includes determining a plurality of vehicle positions, associating each vehicle position with a taxing region, and determining the tax in each taxing region in response to the vehicle positions associated with the taxing region.

For the third method, the step of determining a plurality of vehicle positions is executed as follows. Mobile unit 22 establishes a plurality of position fixes using positioning system 50 or an on-board positioning sensor. Each position fix may be in the form of standard geographical coordinates such as latitude and longitude.

The step of associating each vehicle position with a taxing region is performed as follows. Mobile unit 22 accesses a database that contains information defining a plurality of taxing regions and may comprise coordinates defining regional boundaries, intersections of routes with regional boundaries, or any other information that

allows a processor to determine that vehicle 20 has traveled from one taxing region into another. Mobile unit 22 then associates each position fix with a taxing region in response to the geographical information

5   contained in the database.

In this method the step of determining the tax for vehicle 20 is executed as follows. Mobile unit 22 measures the distance traveled by vehicle 20 between position fixes using odometer 109. As stated before,

10   odometer 109 may be the odometer included in vehicle 20 or a separate odometer. Processor 100 then determines the distance traveled in each taxing region in response to the position fixes associated with that taxing region and the distance measured by odometer 109. The present

15   invention contemplates that processor 100 may determine distance using one of two alternative methods at this step.

Processor 100 determines the amount of mileage recorded by odometer 109 since the last position fix and

20   adds this amount to the distance already recorded for the region. For example, assume vehicle 20 has traveled twenty miles since the last position fix and entered a new taxing region at the second mile. Normally, processor 100 credits twenty miles to the old taxing

25   region. To further refine the distance determination, processor 100 may use the position fix, information contained in the geographical database, and standard geometric equations to calculate approximately at what mileage since the last odometer reading vehicle 20 passed

30   into the new taxing region. Processor 100 then credits a proportionate amount of mileage to the old taxing region and the new taxing region. Processor 100 then adds two miles to the distance traveled in the old region and eighteen miles to the distance traveled in the new

35   region. Processor 100 then determines a tax for each taxing region in response to the distance traveled by

vehicle 20 in that taxing region. A more detailed
explanation of this third method is set forth in the
description for FIGURE 14.

5   FIGURE 9 is a schematic representation of mobile
unit 22. Mobile unit 22 includes mobile positioning
receiver 80, mobile communications device 90, odometer
109, and other associated hardware and software,
described below. Mobile positioning receiver 80 includes
antenna 82, receiver 84, controller 86, and memory 88.

10 In operation, mobile positioning receiver 80 receives
positioning information from satellites 52 over
positioning information streams 54 at antenna 82.
Receiver 84 processes the positioning information to
extract ephemeris, almanac, and clock correction data.

15 Controller 86 receives the positioning information and
computes a position fix. These determinations performed
by controller 86 may use data stored in memory 88.

         Mobile communications device 90 includes an antenna
92, transceiver 94, and a handset 96. In operation,

20 mobile communications device 90 transmits vehicle
information over vehicle information stream 48. The
vehicle information may be received by dispatch 30 using
elements of communications link 40, such as receiver site
44 associated with the cellular telephone network.

25 Mobile communications device 90 can also receive data or
calls transmitted to mobile unit 22 from a remote site,
such as dispatch 30. Handset 96 provides traditional
voice or data communications using mobile communications
device 90.

30   Odometer 109 may be the odometer originally included
with vehicle 20 or a second odometer that is more
integral to mobile unit 22. Odometer 109 measures the
actual distance traveled by vehicle 20. An important
technical advantage of the present invention is provided

35 by odometer 109 because many taxing authorities currently
accept odometer readings as an accurate measurement of

distance traveled by a vehicle. The accuracy of the tax
determination will depend in part upon the accuracy of
odometer 109.

Processor 100 manages the communicating,
calculating, locating, and reporting features of mobile
unit 22. In operation, processor 100 receives a position
fix from controller 86 and a measured distance from
odometer 109. Processor 100 then generates vehicle
information. Determination of tax for vehicle 20 may be
performed by processor 100, by central controller 122 at
dispatch 30, or by a combination of processor 100 and
central controller 122. Processor 100 routes the vehicle
information or determined tax through link 95 or over any
other appropriate path, such as through modem or dual
tone multifrequency (DTMF) coder/decoder 110 and bus
drivers 112 to transceiver 94 of mobile communications
device 90. Transceiver 94 then transmits the vehicle
information or determined tax to dispatch 30 over
communications link 40.

Coupled to processor 100 is memory 102 which may
contain grids, such as region grid 60 or vehicle position
grid 65, programs, maps, geographical databases, and
other information required by processor 100 to perform
its functions. Memory 102 may be random access memory
(RAM), read-only memory (ROM), magnetic media, CD-ROM,
removable memory devices, or any other device that allows
storage or retrieval of data. Processor 100 and
controller 86, as well as memory 102 and memory 88, may
be separate or integral components of mobile unit 22.
Mobile unit 22 contemplates any arrangement, processing
capability, or task assignment between mobile positioning
receiver 80, mobile communications device 90, and
processor 100.

Vehicle information or determined tax may be sent to
output device 104 to generate a map displaying vehicle 20
and the position fixes. Output device 104 can produce

audible information, such as the announcement of a
determined tax and distance traveled in a taxing region
to the operator of vehicle 20.

5   Processor 100 is also coupled to input device 106,
which may be a keypad or touch screen, as well as voice
recognition software and hardware that can accept audible
commands and information. Furthermore, both output
device 104 and input device 106 may include fixed or
removable storage media, such as magnetic computer discs,
10   CD-ROM, or other suitable media to both receive output
from and provide input to processor 100 or memory 102.
The operator of vehicle 20 may input information into
mobile unit 22 when vehicle 20 reaches a significant
vehicle position, such as the boundary of a taxing
15   region. Using input device 106, the operator logs
information about the vehicle position based upon the
position fix for vehicle 20 determined by mobile
positioning receiver 80, actual time and mileage at which
vehicle 20 travels from one taxing region into another,
20   the actual route over which vehicle 20 travels, points
through which vehicle 20 passes, and any other item for
which it is desirable to have a record. The operator may
manually or orally log all of this information into
mobile unit 22, or the operator may cooperate with
25   processor 100 to log the information. For instance,
using input device 106, the operator may manually or
orally record the moment when vehicle 20 reaches a
certain geographic mark, after which processor 100
automatically logs the other items. The geographic mark
30   may be one of the predetermined vehicle positions
discussed above in regard to vehicle position grid 65.
This predetermined vehicle position may be stored in
memory 102 along with the other information. The actual
highway mileage between predetermined vehicle positions,
35   that may be included in the stored information, can later
be retrieved and used to update existing databases, such

as table 70. Thus, on future trips mobile unit 22 or dispatch 30 can then use the information to more accurately determine distance traveled by vehicle 20 between predetermined vehicle positions and the

5   corresponding tax. This information allows the geographic database to be updated "on the fly" as vehicle 20 generates more accurate geographic information.

Processor 100 generates vehicle information for transmission to dispatch 30 using mobile communications

10   device 90. The vehicle information may include position fixes, vehicle positions, actual time and mileage at which vehicle 20 travels from one taxing region into another, the actual route over which vehicle 20 travels, points through which vehicle 20 passes, the determined

15   distance and tax in a taxing region, the time of reporting, or information input by the vehicle operator, as well as any other information collected by processor 100 from various sensors 108. For example, sensors 108 may include various engine sensors, truck trailer

20   sensors, security monitors, or other devices generating information on the status or condition of mobile unit 22, vehicle 20, or its operator. In particular, sensors 108 can be on-board positioning sensors to determine position fixes, alone or in combination with positioning system

25   50.

The generation and transmission of this vehicle information may be based on a determination that vehicle 20 has passed a significant geographic point, an elapsed time, a predetermined time, movement of mobile

30   unit 22, sensor readings, or any other piece of information that may necessitate reporting to a remote location. The vehicle information is sent from processor 100 through modem or DTMF coder/decoder 110 to bus drivers 112, and then to transceiver 94 for transmission

35   over antenna 92 to a remote location, such as dispatch 30 (FIGURE 10). Vehicle information may also be sent

directly to transceiver 94 over link 95. Mobile unit 22
may also include a clock 116 coupled to processor 100
that may be used to synchronize the position fix received
from controller 86 with vehicle information transmitted
5   to transceiver 94.

Components of mobile unit 22 shown in FIGURE 9 may
be packaged into one or more housings. Mobile unit 22
may be mounted to vehicle 20 or an object to be tracked.
Mobile unit 22 may also be packaged as a portable,
10   hand-held device that provides personal timing, locating,
communicating, and reporting functions.

FIGURE 10 is a schematic representation of dispatch
30. Dispatch 30 includes modem or DTMF coder/decoder
120, central controller 122, a memory 124, input/output
15   device 126, and other associated hardware and software.
Memory 124 may be RAM, ROM, CD-ROM, removable memory
devices, or any other device that allows storage or
retrieval of data. Input/output device 126 includes any
variety of output devices, such as a display, a speaker
20   to provide audible information, removable storage media,
or any other appropriate output device. Input/output
device 126 may also include a variety of input devices,
such as a keyboard, mouse, touch screen, removable
storage media, or any other appropriate input device.

25   As discussed above, determination of distance and
tax for vehicle 20 may be performed wholly on vehicle 20
by mobile unit 22 or partly on vehicle 20 by mobile unit
22 and partly at dispatch 30 by central controller 122.
If determinations of distance and tax are performed by
30   mobile unit 22, dispatch 30 receives the determined
distance, tax, or both for vehicle 20 in a taxing region
from communications link 40.

If determinations of distance and tax are not
performed by mobile unit 22, then dispatch 30 receives
35   vehicle information for one or more vehicles 20 carrying
mobile units 22. In particular, vehicle information is

received at central controller 122 through modem or DTMF coder/decoder 120 from communications link 40. Alternatively, reception of vehicle information at dispatch 30 may not require a data encoder. The vehicle

5   information may include position fixes, vehicle positions, corresponding times for each vehicle position, measured distance, actual time and mileage at which vehicle 20 travels from one taxing region into another, route of vehicle 20, operating parameters, and other

10 information. Central controller 122 processes the vehicle information to determine the distance traveled by vehicle 20 in each taxing region and the corresponding tax. The vehicle positions, the determined tax, and the determined distance for each taxing region may be stored

15 in memory 124 and displayed on input/output device 126. Memory 124 may also contain grids, such as region grid 60 or vehicle position grid 65, programs, maps, geographical databases, and other information required by central controller 122 to perform its functions.

20   Central controller 122 may also receive other information from mobile unit 22 and process this information to determine expected time of arrival, locate, track, dispatch, and communicate with mobile unit 22. For example, central controller 122 can maintain a

25 database in memory 124 of all mobile units 22 with their current expected times of arrival, location, status, and relevant sensor readings. This database can also be used to initiate communication with mobile unit 22. Furthermore, central controller 122 may perform a call

30 delivery function that routes incoming calls to mobile. unit 22 through communications link 40.

         FIGURE 11 is a flow chart of a method for determining tax using region grid 60 shown in FIGURES 2 and 3. The following explanation of the method

35 illustrated in FIGURE 11 assumes that all steps are performed on vehicle 20.

Initially, processor 100 of mobile unit 22, some other on-board or remote device, or a person generates region grid 60 (at 210), comprising a plurality of cells, each cell associated with a taxing region. The taxing
5   regions may represent countries, states, counties, districts, cities, or any other region for which it is desirable to determine a tax. Processor 100 next initializes the region, distance traveled by vehicle 20 in the region, and tax for the region (at 212).

10   Receiver 84 of mobile positioning receiver 80 processes positioning information received from satellites 52, and controller 86 determines a position fix. Alternatively, an on-board positioning sensor establishes a position fix. Processor 100 receives the
15   position fix, from either mobile positioning receiver 80 or the on-board positioning sensor, defining a leg of the route traveled by vehicle 20. Processor 100 determines an initial vehicle position representing the beginning of the leg defined by the position fixes (at 214). Based
20   upon the information contained in region grid 60 and other information that may be contained within memory 102, processor 100 relates the vehicle position to a region (at 216).

Processor 100 determines (at 218) whether the region
25   is the same as before. If the region is not the same as before, processor 100 determines the tax for the old region (at 220). Processor 100 stores (at 222) the old region, distance traveled in that region, and the determined tax for the region within memory 102.
30   Processor 100 sets the region to the new region (at 224). Processor 100 initializes the distance and tax for the new region (at 226). Processor 100 increments the distance in the current region (at 228). The step of incrementing the distance may be performed using vehicle
35   positions or by reading mileage from odometer 109. If the region is the same, processor 100 skips to the step

of incrementing distance in the current region (at 228).
Mobile unit 22 then returns to the step of determining a
vehicle position (at 214).

FIGURE 12 is a flow chart of an alternative method
for determining tax using region grid 60 shown in
FIGURES 2 and 3. This method segments each leg of the
route defined by position fixes into numerous vehicle
positions. Again, this method may be performed by mobile
unit 22, dispatch 30, or a combination of mobile unit 22
and dispatch 30. The segmentation of position fixes into
numerous vehicle positions may be performed after mobile
unit 22 has collected a number of position fixes.
Therefore, the method described with reference to FIGURE
12 may be more effectively performed at dispatch 30 or
host 35, where more processing capability and data
storage is available. However, to promote clarity in
description among the different methods, the following
explanation assumes that all steps are performed by
mobile unit 22 on vehicle 20.

Initially, processor 100 of mobile unit 22 generates
region grid 60 (at 310) comprising a plurality of cells,
each cell associated with a taxing region. Processor 100
initializes the region, the distance traveled by vehicle
20 in the region, and the tax for the region (at 312).
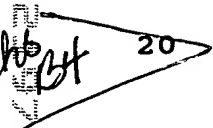Processor 100 sets a new position fix to an old position
fix (at 313).

Receiver 84 of mobile positioning receiver 80
processes positioning information received from
satellites 52, and controller 86 determines a new
position fix (at 314). Alternatively, an on-board
positioning sensor establishes a new position fix.
Processor 100 receives the new position fix from either
mobile positioning receiver 80 or the on-board
positioning sensor. Based upon this information and
other information that may be contained within memory
102, processor 100 determines a route between the old

position fix and the new position fix (at 316).
Processor 100 specifies a sequence of vehicle positions
along the route (at 318). These vehicle positions can be
spaced at equal distances along the route.

5   Processor 100 increments to the next vehicle
position along the route toward the new position fix (at
320). Based upon the information contained in region
grid 60, processor 100 relates the vehicle position to a
taxing region (at 322). Processor 100 then increments

10 distance (at 324) within the current region. The step of
incrementing the distance may be performed using vehicle
positions or by reading mileage from odometer 109.

    Processor 100 next determines (at 328) whether the
region is the same as before. If the region is not the

15 same, processor 100 determines the tax for the old region
(at 326) and stores the old region, the distance traveled
by vehicle 20 in that region, and the determined tax for
that region (at 330). Processor 100 initializes the
distance and tax (at 332) and sets the region to the new

20 region (at 334).

    If the region is the same as before, processor 100
skips the steps of storing (330), initializing (332), and
setting (334) and determines (at 336) whether the vehicle
positions have reached the new position fix. If the

25 vehicle positions have reached the new position fix,
mobile unit 22 returns to the step of determining a new
position fix. If the vehicle positions have not reached
the new position fix, mobile unit 22 returns to the step
of incrementing vehicle positions along the route toward

30 the new position fix.

    FIGURE 13 is a flow chart of a method for
determining tax for vehicle 20 using vehicle position
grid 65 shown in FIGURES 4 and 5. The following
explanation of the method illustrated in FIGURE 13

35 assumes that all steps are performed on vehicle 20.

Initially, processor 100 at mobile unit 22 generates
vehicle position grid 65 and table 70 (at 410). Vehicle
position grid 65 comprises a plurality of cells, each
cell associated with a predetermined vehicle position.

5   Several cells may contain the same predetermined vehicle
position. Table 70 contains information about the
distance and the tax for each region between different
predetermined vehicle positions. Processor 100 then
initializes the vehicle position (at 412).

10   Receiver 84 of mobile positioning receiver 80
processes positioning information received from
satellites 52. Controller 86 determines a position fix
(at 414). In the alternative, an on-board positioning
sensor establishes a position fix. Processor 100

15   receives the position fix from either mobile positioning
receiver 80 or the on-board position sensor. Based upon
the information contained in vehicle position grid 65,
processor 100 associates the position fix with one of the
predetermined vehicle positions (at 416).

20   Processor 100 next determines (at 418) whether the
vehicle position is the same as before. If the vehicle
position is the same as before, mobile unit 22 returns to
the step of determining the position fix (at 414).
Processor 100 reconstructs (at 424) a route traveled by

25   vehicle 20 in response to the vehicle positions.
Processor 100 records the old vehicle position in memory
102 or output device 104 (at 428). By referencing table
70, processor 100 determines the distance traveled by
vehicle 20 in each taxing region between the vehicle

30   positions (at 430). Processor 100 may also augment or ·
supplement the distance determination by reading mileage
from odometer 109. Next, processor 100 determines the
tax in each taxing region between vehicle positions by
referencing table 70 (at 432). Processor 100 then sets

35   the vehicle position to the new vehicle position (at

434). Mobile unit 22 returns to the step of determining a position fix (at 414).

FIGURE 14 is a flow chart for the third method for determining tax of a vehicle as shown in operation using the map illustrated in FIGURES 7 and 8. Initially, processor 100 generates a geographical database (at 510). The geographical database comprises information that allows processor 100 to determine at what point vehicle 20 traveled from one taxing region into another, such as geographical coordinates defining regional boundaries or the intersections of routes with regional boundaries. Processor 100 then initializes the distance by recording the reading on odometer 109, and the vehicle position (at 512).

Receiver 84 of mobile positioning receiver 80 processes positioning information received from satellites 52. Controller 86 determines a position fix (at 514). Alternatively, an on-board positioning sensor establishes a position fix. Processor 100 receives the position fix from either mobile positioning receiver 80 or the on-board positioning sensor. Based upon the position fix and information contained within the geographical database, processor 100 determines the taxing region in which vehicle 20 is located (at 516). Processor 100 reads odometer 109 (at 517) to obtain a measured distance.

Processor 100 determines (at 518) whether the region is the same as before. If the region is not the same, processor 100 updates the distance in the old region (at 520) based upon the distance measured by odometer 109 and the information contained in the geographical database. As discussed above, processor 100 may either credit all the distance to the old region or credit a proportionate amount of the distance to each of the old region and the new region. Processor 100 then determines the tax for the old region (at 522) based upon the distance traveled

in the old region. Processor 100 stores the old region, the distance traveled by vehicle 20 in that region, and the determined tax for the region (at 524). Processor 100 initializes the distance (at 526) and updates the region to the new region (at 528).

If the region is the same as before, processor 100 skips the steps of updating in the old region (520), determining tax (522), storing (524), initializing (526), and updating the region (528). Processor 100 then updates the distance traveled in the current region using the distance measured by odometer 109, the position fix, and the information contained in the geographical database (at 530).

Although the present invention has been described with several embodiments, a myriad of changes, variations, alterations, transformations, and modifications may be suggested to one skilled in the art, and it is intended that the present invention encompass such changes, variations, alterations, transformations, and modifications as fall within the scope of the appended claims.